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The Nonconductive Sputtered Thin Film Layer

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Anotace:
Práce se zabývá tematikou dielektrických vrstev vytvořených tenkovrstvými technologiemi. Sada tenkovrstvých kondenzátorů byla připravena pomocí metody naprašování a vakuového napařování. Dielektrická vrstva byla nanášena při různých podmínkách naprašovacího procesu. Dielektická vrstva Al_2O_3 byla naprašována na skleněnou podložku. Měřenými parametry byly elektrická kapacita a tloušťka vrstvy. Tloušťka byla určena pomocí zařízení vyžívajícího hrotovou metodu. Vyhodnocovala se závislost elektrické kapacity a tloušťky tenkovrstvého kondenzátoru v závislosti na podmínkách procesu naprašování – výkon plasmy a čas depozice.

Annotation:
The work is focused on topic of dielectrics layers prepared by thin film layer technology, specifically by sputtering. Set of samples of thin film capacitors was prepared. Samples differ by different conditions of preparation of dielectric layer. Dielectric layers were deposited by sputtering of Al_2O_3 on glass substrate. The measured parameters were the electrical capacity and thickness of the dielectric layer. Thickness was obtained with help of device using the stylus method. The main evaluated parameters are the capacity and thickness of thin film capacitors in dependence on the deposition process conditions – plasma power and deposition time.

INTRODUCTION

Thin film layers are now used on a large scale, each of us encounters them daily. They can be found on semiconductor contacts, Schottky barriers, photovoltaic panels and also on the surface of the drills or in the form of a reflective layer on the mirrors [1]. Technologies of thin film are applied to nanomaterials used in electronic applications and other areas [2]. In the future, the use of these technologies is likely to be extended to new areas of industry and people's daily lives, which will put pressure on both the continuous improvement of thin film quality and the reduction of economic costs of production and search for new applications of this technology.

SAMPLES PREPARATION

The samples with a thin-film dielectric layers on glass substrates was prepared for the experiment. The glass substrate provides a smooth surface, which is important for deposition of layer with thickness of several tens of nm. Topology of sample is shown in Fig. 1. Electrodes of capacitors were created by vacuum evaporation of aluminium. The electrodes are shown in gray in the figure. The dielectric layer is deposited between the electrodes. Layer was prepared by sputtering of Al_2O_3. The 10 capacitors are formed on the substrate at the point where the electrodes overlap. Capacitors have a rectangular area with sides of 0.7 mm x 0.8 mm.

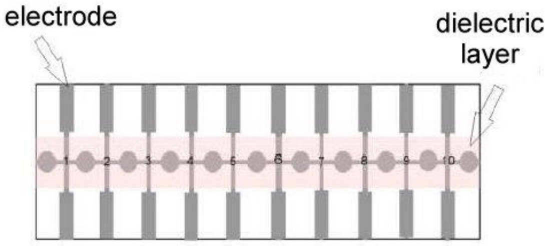

Fig. 1 Substrate with thin film capacitors

The dielectric of Al_2O_3 layers were sputtered under different conditions. Variable conditions of sputtering process were power of plasma and time of deposition. Capacitor samples were generated using a combination of 3 plasma power values and 3 deposition times. Pressure of inert atmosphere in vacuum chamber during sputtering process was constant for all samples and reached 2 Pa. The distance between the source material target and the substrate was 70 mm. The diameter of the target was 2 inches. More information about sputtering technology can be found for example in [3][4].

PARAMETERS OF DIELECTRIC LAYERS

Two parameters of the dielectric layer were measured - electrical capacity and thickness. Electrical capacity was measured by RLCG meter. Thickness was determined by the stylus method using a FORM TALYSURF device. The principle of measurement is to move a very sensitive tip over the sample surface.

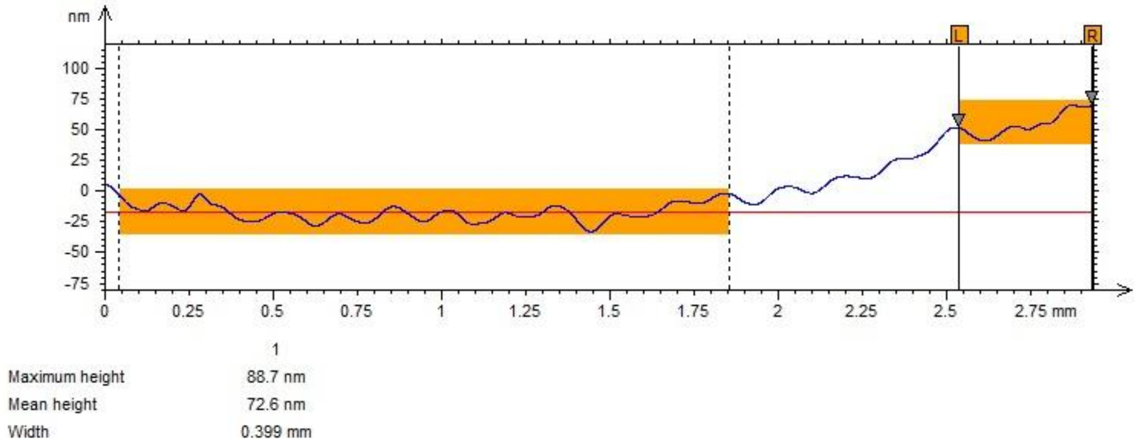

Fig. 2 Scanned and edited layer profile

The vertical movement of the tip is converted to an electrical signal by means of an inductive gauge. An example of the scanned, filtered and edited layer profile is shown in Fig. 2. Section delimited by dashed lines is reference line set to the substrate level. The part of the profile delimited by solid lines marked L and P is the measured dielectric layer. A more detailed description of the method and apparatus used for thickness measurement can be found, for example, in lit [5].

RESULTS DISCUSSION

Electrical capacity

The graph in Fig. 3 shows the dependence of electrical capacity on plasma power and deposition time.

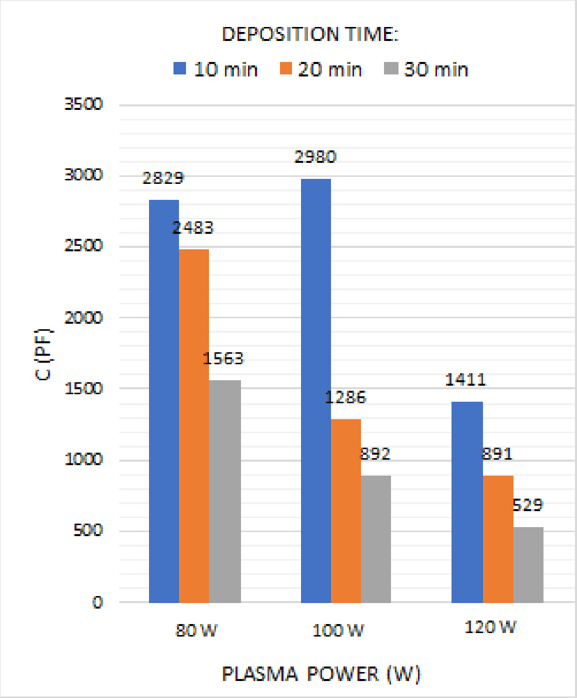

Fig. 3 Dependence of electrical capacity on conditions of sputtering process

As the deposition time increases, the capacity of capacitors decreases. This is given the fact that the longer the deposition layer, the thicker the dielectric and the appearance to the fact that the capacitor capacitance is inversely proportional to the dielectric thickness in it, then the capacitance these capacitors decrease with increasing deposition time. Well know relationship applies to capacity and dimensions of capacitors:

$$C = \varepsilon \cdot \frac{S}{d} \tag{1}$$

where C is capacity, ε is dielectric constant, S is rectangle area of electrodes and d is thickness of dielectric (distance between electrodes). From fig. 3 we can see that capacity of sample prepared 10 minutes at plasma power 80 W is lower than expected than the sample prepared 10 minutes at plasma power 100 W. This deviation is most likely caused by the fact that the layers produced for the shortest time are the most vulnerable to errors. At short deposition times, fluctuation of plasma power at beginning of sputtering process will be most apparent.

Thickness

Fig. 4 shows the dependence of the layer thickness on the plasma power and deposition time. As expected, a thicker layer is deposited to the substrate at higher power and longer times. According to equation 1, relationship C·d=ε·S is valid. The electrode area S is the same for all capacitors. Suppose that for the thickness range considered, dielectric constant ε will not change. Then the capacity C times thickness d should be theoretically constant for all samples, i.e. C·d = const. These calculations for the capacitors deposited at all 9 combinations of the sputtering process conditions are summarized in Tab 1.

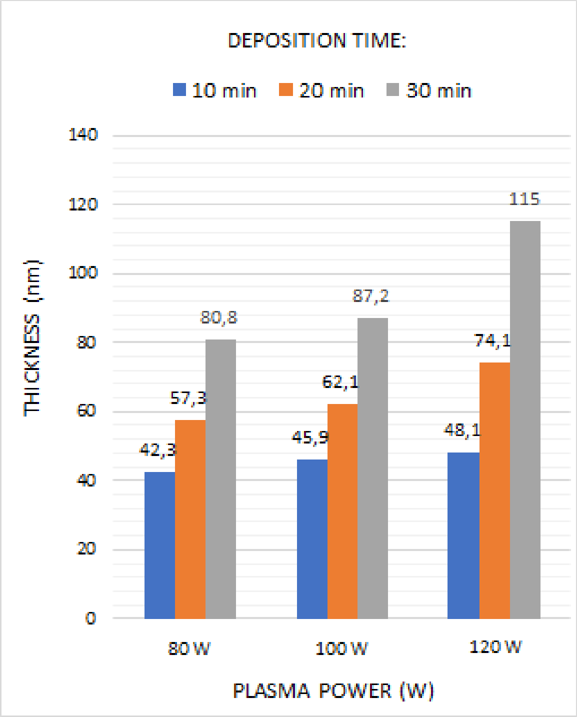

Fig. 4 Dependence of layer thickness on conditions of sputtering process

The C·d values vary for different sputtering conditions. These values are greatest for thinner layers. The main cause of these deviations is probably to be the thickness evaluation. By copying the sample surface during scanning, the entire process is particularly vulnerable to non-flat substrate.

Tab 1 Values of electrical capacity vs thickness

Power (W) /time (min)	**C (nF)**	**d (nm)**	**C· d**
80/10	2.829	4.3	119.7
80/20	2.483	57.3	142.3
80/30	1.563	80.8	126.3
100/10	2.980	45.9	136.8
100/20	1.286	62.1	79.9
100/30	0.892	87.2	77.8
120/10	1.411	48.1	67.9
120/20	0.891	74.1	66.0
120/30	0.529	115	60.8

Measuring of thinner layers is more problematic due to non-flat substrate. A larger error is introduced in the measurement than in the measurement of thicker layers.

CONCLUSIONS

Sample parameters were evaluated to a relatively small extent in terms of plasma power levels and deposition times in the sputtering process. Non-flat surface of the substrate significantly affects the results of the evaluated thickness. To some extent, results may also be affected by electrical capacity measurement errors. The question is also how much the structure of the dielectric layer is affected by the power of plasma during sputtering. At higher powers, particles sputtered from target can be deposit on the substrate in larger clusters.

LITERATURA - REFERENCES

[1] Edgar, A., Jairo, O., Cubillos, G.; Thin Film Growth Through Sputtering Technique and Its Applications, In book Crystallization - Science and Technology, 2012.

[2] Aaron D. Franklin; Nanomaterials in transistors: From high-performance to thin-film applications, Science 14 Aug 2015, Vol. 349, Issue 6249.

[3] Wasa, K., Kitabatake, M., Adachi, H.; Thin Film Material Technology, Springer, 2004, ISBN 0-8155-1483-2.

[4] Sarangan, A.; Fundamentals and Applications of Nanophotonics, Woodhead Publishing, 2016, chapter 5, ISBN 9781782424642.

[5] Beshajová Pelikánová, I.; The Influence of Viscosity of Thick Film Pastes on Quality of Printed Structures, In Electronic Devices and Systems Conference 2012. Juni, Brno, 2012, pp. 283 - 288, ISBN 978-80-214-4539-0.